

I claim:

1. A process for converting an alkane to an oxygenated product comprising:

passing an alkane in a gas state over a first fixed bed containing a first bromide salt in a solid state to produce an alkyl bromide in a gas state, a hydrobromic acid in a gas state and a second bromide salt in a solid state, wherein said second bromide salt is retained in said first fixed bed and further wherein said first and second bromide salts include a transition metal having a higher valence state and a lower valence state and said transition metal is at said higher valence state in said first bromide salt and at said lower valence state in said second bromide salt;

5 10 passing said hydrobromic acid over a second fixed bed containing a metal oxide in a solid state to produce water in a gas state and said first bromide salt in a solid state, wherein said first bromide salt is retained in said second fixed bed;

passing said alkyl bromide over said second fixed bed in the presence of said water to produce an oxygenated product in a gas state and said first bromide salt in a solid state, wherein said first bromide salt is retained in said second fixed bed;

15 regenerating said metal oxide in said second fixed bed by passing oxygen over said second fixed bed, thereby reacting said oxygen with said first bromide salt in said second fixed bed to produce said metal oxide in a solid state and bromine in a gas state, wherein said metal oxide is retained in said second fixed bed; and

20 regenerating said first bromide salt in said first fixed bed by passing said bromine over said first fixed bed, thereby reacting said bromine with said second bromide salt in said first fixed bed to produce said first bromide salt, wherein said first bromide salt is retained in said first fixed bed.

25 2. The process of claim 1 wherein said first bromide salt in said first fixed bed is fixed on a support.

3. The process of claim 1 wherein said first fixed bed is purged by passing an unreactive gas over said first fixed bed to remove any hydrocarbons from said first fixed bed before regenerating said first bromide salt in said first fixed bed and said metal oxide in said second fixed bed.

30 4. The process of claim 1 wherein said first fixed bed is purged by passing an

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unreactive gas over said first fixed bed to remove any oxygen from said first fixed bed after regenerating said first bromide salt in said first fixed bed and said metal oxide in said second fixed bed.

5. The process of claim 1 wherein said metal oxide in said second fixed bed is fixed on a support.

6. The process of claim 1 wherein said second fixed bed is purged by passing an unreactive gas over said second fixed bed to remove any hydrocarbons from said second fixed bed before regenerating said first bromide salt in said first fixed bed and said metal oxide in said second fixed bed.

10 7. The process of claim 1 wherein said second fixed bed is purged by passing an unreactive gas over said second fixed bed to remove any oxygen from said second fixed bed after regenerating said first bromide salt in said first fixed bed and said metal oxide in said second fixed bed.

15 8. The process of claim 1 wherein said oxygen is passed over said second fixed bed by passing air containing said oxygen over said second fixed bed.

9. The process of claim 1 wherein said oxygenated product is an alcohol or an ether.

10. The process of claim 1 wherein said metal oxide includes a metal and said metal of said metal oxide is a transition metal or an alkaline earth metal.

20 11. The process of claim 1 wherein said metal oxide includes a transition metal essentially identical to said transition metal of said first and second bromine salts.

12. The process of claim 1 wherein said first fixed bed and said second fixed bed are contained within a single reactor vessel.

25 13. The process of claim 1 wherein said first fixed bed is contained within a first reactor vessel and said second fixed bed is contained within a second reactor vessel.

14. The process of claim 1 further comprising cyclically repeating one or more times said steps of passing said alkane over said first fixed bed, passing said alkyl bromide and said hydrobromic acid over said second fixed bed, and regenerating said first bromide salt in said first fixed bed and said metal oxide in said second fixed bed.

30 15. The process of claim 1 wherein said steps of passing said alkane over said

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first fixed bed and passing said alkyl bromide and said hydrobromic acid over said second fixed bed are suspended while regenerating said first bromide salt in said first fixed bed and said metal oxide in said second fixed bed, and further wherein said steps of regenerating said first bromide salt in said first fixed bed and said metal oxide in said second fixed bed are suspended while passing said alkane over said first fixed bed and passing said alkyl bromide and said hydrobromic acid over said second fixed bed.

5 16. The process of claim 15 further comprising passing said alkane over a third fixed bed containing a third bromide salt and passing an alkyl bromide and a hydrobromic acid from said third fixed bed over a fourth fixed bed containing a second metal oxide while said steps of passing said alkane over said first fixed bed and passing said alkyl bromide and said hydrobromic acid over said second fixed bed are suspended, wherein said first and third bromide salts are essentially identical or said third bromide salt includes a transition metal different from said transition metal of said first bromide salt and said metal oxide contained in said second fixed bed is a first metal oxide and said first and second metal oxides are essentially identical or said second metal oxide includes a metal different from said metal of said first metal oxide.

10 17. The process of claim 16 further comprising regenerating said third bromide salt in said third fixed bed and said second metal oxide in said fourth fixed bed while passing said alkane over said first fixed bed and passing said alkyl bromide and said hydrobromic acid over said second fixed bed.

15 18. A process for converting an alkane to an oxygenated product comprising: reacting an alkane with a first bromide salt in a first reactor to produce an alkyl bromide, a hydrobromic acid, and a second bromide salt, wherein said first and second bromide salts include a transition metal having a higher valence state and a lower valence state and said transition metal is at said higher valence state in said first bromide salt and at said lower valence state in said second bromide salt;

20 reacting said hydrobromic acid with a metal oxide in a second reactor to produce water and said first bromide salt;

25 reacting said alkyl bromide with said metal oxide and said water in said second reactor to produce an oxygenated product and said first bromide salt;

purging said first and second reactors with an unreactive gas to remove any hydrocarbons from said first and second reactors;

regenerating said metal oxide in said second reactor by reacting oxygen with said first bromide salt in said second reactor to produce said metal oxide and bromine;

5 regenerating said first bromide salt in said first reactor by reacting said bromine with said second bromide salt in said first reactor to produce said first bromide salt; and

purging said first and second reactors with an unreactive gas to remove any oxygen from said first and second reactors.

19. The process of claim 18 wherein said first bromide salt in said first reactor is fixed on a support in a first fixed bed.

20. The process of claim 18 wherein said metal oxide in said second reactor is fixed on a support in a second fixed bed.

21. The process of claim 18 wherein said oxygen reacting with said first bromide salt in said second reactor is contained within air fed to said second reactor.

15 22. The process of claim 18 wherein said oxygenated product is an alcohol or an ether.

23. The process of claim 18 wherein said metal oxide includes a metal and said metal of said metal oxide is a transition metal or an alkaline earth metal.

20 24. The process of claim 18 wherein said metal oxide includes a transition metal essentially identical to said transition metal of said first and second bromine salts.

25. The process of claim 18 wherein said first reactor and said second reactor are included within a single reactor vessel.

26. The process of claim 18 wherein said first reactor is included within a first reactor vessel and said second reactor is included within a second reactor vessel.

25 27. The process of claim 18 further comprising cyclically repeating one or more times said steps of reacting said alkane in said first reactor, reacting said alkyl bromide and said hydrobromic acid in said second reactor, purging said first and second reactors, regenerating said metal oxide in said second reactor and said first bromide salt in said first reactor, and purging said first and second reactors.

30 28. The process of claim 18 wherein said steps of reacting said alkane in said

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first reactor and reacting said alkyl bromide and said hydrobromic acid in said second reactor are suspended while regenerating said metal oxide in said second reactor and said first bromide salt in said first reactor, and further wherein said steps of regenerating said metal oxide in said second reactor and said first bromide salt in said 5 first reactor are suspended while reacting said alkane in said first reactor and reacting said alkyl bromide and said hydrobromic acid in said second reactor.

29. The process of claim 28 further comprising reacting said alkane in a third reactor with a third bromide salt and reacting an alkyl bromide and a hydrobromic acid from said third reactor in a fourth reactor with a second metal oxide while said steps of 10 reacting said alkane in said first reactor and reacting said alkyl bromide and said hydrobromic acid in said second reactor are suspended, wherein said first and third bromide salts are essentially identical or said third bromide salt includes a transition metal different from said transition metal of said first bromide salt and said metal oxide in said second reactor is a first metal oxide and said first and second metal oxides are 15 essentially identical or said second metal oxide includes a metal different from said metal of said first metal oxide.

30. The process of claim 29 further comprising regenerating said second metal oxide in said fourth reactor and said third bromide salt in said third reactor while reacting said alkane in said first reactor and reacting said alkyl bromide and said hydrobromic acid in said second reactor. 20

31. A process for converting an alkane to an oxygenated product comprising:
passing an alkane in a gas state over a first fixed bed containing a first bromide salt in a solid state to produce an alkyl bromide in a gas state, a hydrobromic acid in a gas state and a second bromide salt in a solid state, wherein said second bromide salt 25 is retained in said first fixed bed and further wherein said first and second bromide salts include a transition metal having a higher valence state and a lower valence state and said transition metal is at said higher valence state in said first bromide salt and at said lower valence state in said second bromide salt;

passing said hydrobromic acid over a second fixed bed containing a metal oxide 30 in a solid state to produce water in a gas state and said first bromide salt in a solid

state, wherein said first bromide salt is retained in said second fixed bed;

passing said alkyl bromide over said second fixed bed in the presence of said water to produce an oxygenated product in a gas state and said first bromide salt in a solid state, wherein said first bromide salt is retained in said second fixed bed;

5 purging said first and second fixed beds with an unreactive gas to remove any hydrocarbons from said first and second fixed beds;

regenerating said metal oxide in said second fixed bed by passing oxygen over said second fixed bed, thereby reacting said oxygen with said first bromide salt in said second fixed bed to produce said metal oxide in a solid state and bromine in a gas state, wherein said metal oxide is retained in said second fixed bed;

10 regenerating said first bromide salt in said first fixed bed by passing said bromine over said first fixed bed, thereby reacting said bromine with said second bromide salt in said first fixed bed to produce said first bromide salt, wherein said first bromide salt is retained in said second fixed bed; and

15 purging said first and second fixed beds with an unreactive gas to remove any hydrocarbons from said first and second fixed beds.

32. A process for converting an alkane to an oxygenated product comprising:

passing an alkane in a gas state over a first fixed bed containing a first bromide salt in a solid state to produce an alkyl bromide in a gas state, a hydrobromic acid in a 20 gas state and a second bromide salt in a solid state, wherein said first and second bromide salts include a transition metal having a higher valence state and a lower valence state and said transition metal is at said higher valence state in said first bromide salt and at said lower valence state in said second bromide salt;

25 passing said hydrobromic acid over a second fixed bed containing a metal oxide in a solid state to produce water in a gas state and said first bromide salt in a solid state; and

passing said alkyl bromide over said second fixed bed in the presence of said water to produce an oxygenated product in a gas state and said first bromide salt in a solid state.

30 33. A process for regenerating materials used in an alkane to an oxygenated

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product conversion process comprising:

regenerating a metal oxide in a first fixed bed by passing oxygen over said first fixed bed, thereby reacting said oxygen with a first bromide salt in said first fixed bed to produce said metal oxide in a solid state and bromine in a gas state; and

5 regenerating said first bromide salt in a second fixed bed by passing said bromine over said second fixed bed, thereby reacting said bromine with a second bromide salt in said second fixed bed to produce said first bromide salt, wherein said first and second bromide salts include a transition metal having a higher valence state and a lower valence state and said transition metal is at said higher valence state in
10 said first bromide salt and at said lower valence state in said second bromide salt.